Environmental Protection Agency

Heavy-Duty Engine Dynamometer Speed and Torque Calibration Procedure

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NVFEL Reference Number

251

Implementation Approval

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Revision Description

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Attachments

1. Purpose

The purpose of this procedure is to ensure accurate dynamometer calibration by adjusting the torque measuring equipment to a known value introduced by hanging National Institute of Standards and Technology (NIST) -traceable weights on a lever arm. The resulting calibration is verified over the typical measurement range of the dynamometer.

This procedure also contains a verification of the speed measurement system, made by comparing readings from the speed signal and data acquisition system to a frequency counter used as a reference.

2. Test Article Description

Electric Engine Dynamometer, General Electric Model 42 G 408 AD

3. References

3.1 "Code of Federal Regulations," Title 40, Part 86, Subpart N, Sections 86.1308, 86.1316, and 86.1318

3.2 "Digalog Cellmate Toolbox User Manual"

4. Required Equipment

4.1 Electric Engine Dynamometer

Equipment used: General Electric Model 42 G 408 AD

4.2 Weights and hangers, certified traceable to NIST

Equipment used: Weights manufactured to Engineering Operation Division (EOD) specifications

4.3 Balanced shaft-torque lever arm, 60.0 inches in overall length with an effective lever arm of 30.0 inches

Equipment used: Torque lever arm manufactured to EOD specifications

4.4 Case-torque lever arm with an effective lever arm of 36.0 inches

Equipment used: Torque lever arm provided with General Electric Model 42 G 408 AD dynamometer

4.5 Dynamometer Controller

Equipment used: Digalog Model Cellmate II

4.6 Speed and Torque Signal Conditioners

Equipment used: Daytronic Models, 9178A, 9140 ("Daytronic")

4.7 Digital Multi-Counter

Equipment used: Fluke Model 1900 Multi-Counter

4.8 Computer

Equipment used: Macintosh with Excel® application

4.9 Protractor level

4.10 Hydraulic lift

4.11 Form 251-01, "Heavy-Duty Dynamometer Speed and Torque Calibration" (Attachment A)

5. Precautions

5.1 Personnel handling the weights must wear protective footwear.

5.2 Never place feet or hands under hanging weights.

5.3 Always turn the power off to all three GE Cabinets, #2, #3 and #5, before opening their access doors.

6. Visual Inspections

All visual inspections are included as part of the test article preparation and procedure.

7. Test Article Preparation

7.1 Assemble the required weights, lever arm, digital multi-counter, hydraulic lift and Form 251-01. Inspect the calibration sticker on the digital multi-counter to ensure that it is in calibration.

7.2 Arrange for the test cell air handling unit to be turned off. Air currents will cause the weights to swing, making the readings unstable.

7.3 Disassemble the driveshaft from the dynamometer shaft.

7.4 Assemble the shaft-torque lever arm to the dynamometer shaft.

Align the bolt holes in the lever arm with those on the dyno shaft; insert three bolts and tighten them securely. Do not overtighten the bolts, as this may damage the aluminum arm.

7.5 Assemble the dyno lock to the rear of the dynamometer shaft. Use two bolts to secure the lock to the shaft. The legs of the lock have adjustable feet to secure it in place and prevent the shaft from rotating.

7.6 Using a protractor level, ensure that the arm is secured in a horizontal position, approximately 5 degrees higher on the side to which the weights will be added. The arm will deflect downward as the weights are added.

Note: The dyno is typically calibrated for engines that rotate in a clockwise direction. The weights will be added to the right side of the lever arm (facing the dyno from the position of the engine.)

7.7 For ease of handling, arrange the weights in the order listed on Form 251-01. All weights are stamped with an identification number.

7.8 Ensure that the AC power is switched to Dyno 2. To verify or change power to the dynos:

7.8.1 Turn the rotating switches on the front of G.E. Cabinet #2 labeled “AC DISCONNECT” and G.E. Cabinet #3 labeled “LINE SWITCH” to “OFF.” Switch the circuit breaker on the side of G.E. Cabinet #5 to “OFF.”

This step must be completed as a safety requirement to ensure that the power is off when opening the cabinet.

7.8.2 Open Cabinet #3 and check the position of the knife switches.

7.8.3 When the switches are to the right side, Dyno #1 is energized. When they are to the left side, Dyno #2 is energized. Move them to the proper position, if necessary.

7.8.4 Close the cabinet and switch the circuit breaker (Cabinet #5) "ON" and then turn the rotating switches "AC DISCONNECT" (Cabinet #2) and "LINE SWITCH" (Cabinet #3) "ON."

7.9 Activate the Cellmate II:

Note: The symbols < > are used to indicate a key on either the Cellmate II Computer Control System or Macintosh computer keyboards.

Example: Press <Return> to enter. This means that you need to press the key labeled "Return" to enter information typed on the computer screen.

7.9.1 Press the yellow power button on the Cellmate II front panel. It will illuminate when the power is "ON."

7.9.2 Press <Caps Lock>. Ensure that the LED on this key is illuminated.

7.9.3 The Cellmate II will prompt "hi." Respond by typing "HI" and press <Return>.

The Cellmate II will now load its programming. A red light to the right of the screen will blink while it is performing any operation. No entries can be made until it has completed this operation. The "TESTING MENU" will appear on the screen when the loading sequence is finished.

7.9.4 Press <2> <Return>. This will display the "TEST SEQUENCES" screen.

7.9.5 Press <2> <Return>. This will display the "TRANSIENT TESTS" screen.

7.9.6 Press <4> <Return>. This will display real-time measurements of test parameters.

7.9.7 Hold down <CTRL> and press <NEXT DISP> (upper left of keyboard). A new display will appear. Repeat <CTRL> <NEXT DISP> to move to the next screen which will display the shaft torque, case torque, and speed.

7.10 Press the green "START" button above the "MG SET" label. The button will illuminate when the motor/generator (MG) set is operating. Operating the MG set ensures that the dyno armature is floating on a film of oil.

8. Test Procedure

100 Shaft-Torque Daytronic Calibration

101 On Form 251-01, in the box labeled "Prev. Shaft Torque Shunt Value," record the shunt value that is displayed on the sticker adjacent to the "Shaft Torque" Daytronic.

102 Adjust the "Shaft Torque" Daytronic signal conditioner display to exactly 0.0 by rotating the "Fine Balance" potentiometer.

103 Hang all the calibration weights on the shaft-torque lever arm. Refer to Form 251-01 for the weights to be used. Weights must not swing on the lever arm during calibration.

104 Adjust the "Shaft Torque" Daytronic so the display matches the total moment created by the lever arm. To do this, adjust the span potentiometer so the display reads 1237.0. The Daytronic is adjustable to ±0.5.

Note: All weights hanging on the lever arm will equal 494.74 lb x 2.5 ft = 1236.8 ft-lb.

105 Using the hydraulic lift, raise the weights and the hanger off the lever arm clevis to recheck the zero calibration. Adjust the "Shaft Torque" Daytronic signal conditioner display to exactly 0.0, if necessary, by turning the "Fine Balance" potentiometer.

106 Repeat Steps 102-105 for zero and span until the "Shaft Torque" Daytronic readings are correct and repeatable.

107 Press the "-CAL" button on the "Shaft Torque" Daytronic. The value that is displayed will be the new shunt calibration value. On a new adhesive sticker, record this value, your initials, and the date. Remove the old sticker and post the new sticker next to the display.

108 On Form 251-01, record the new shunt calibration value in the box labeled "New Shaft Torque Shunt Value." This value should not differ by more than 5 percent from the "Prev Shaft Torque Shunt Value" unless repairs have been made or new equipment has been installed.

If it does differ by more than 5 percent, notify the Calibration and Maintenance (C&M) supervisor.

109 Remove the weights from the hanger, and set the weights and hanger aside.

110 Verify that the Cellmate II display for “SHAFT TORQUE” agrees exactly with the Daytronic reading for zero. Press the “-CAL” button on the “Shaft Torque” Daytronic, and again, ensure that the readings on the two displays agree exactly.

If the readings do not agree, proceed with Section 200.

If the readings agree, proceed with Section 300.

200 Cellmate II Shaft-Torque Calibration

This section should only be used if the “SHAFT TORQUE” readings on the Cellmate II display did not agree with the “Shaft Torque” Daytronic readings for the zero and span as observed in Section 100.

201 Press <MENU>. This will display the “TESTING MENU” screen.

202 Press <1><Return>. This will display the calibration screen.

203 Using <PAGE⇑>, scroll to the calibration screen that displays “TORQUE."

204 Using <⇑> or <⇓>, scroll to “TORQUE." It will become highlighted.

205 Press <Return> on the Cellmate II keyboard to enter the calibration mode.

206 Enter your initials and press <Return>.

Note: If at any point you do not want to change an entry on the Cellmate II, press <Return> and the entry currently on the screen will be retained.

207 Enter the transducer serial number and press <Return>.

Note: This number only needs to be changed if the transducer is replaced.

208 With the weights raised off the clevis, and the “Shaft Torque” Daytronic display reading 0.0, press <Return> to enter the zero calibration into the Cellmate II.

209 Enter “0.0” and press <Return> to enter the appropriate value in the “Low Engineering Value” field.

210 Press and hold the “Shaft Torque” Daytronic “+CAL” button to display the new shunt value. With the “Shaft Torque” Daytronic reading the shunt value, press <Return> to enter the high value of the calibration into the Cellmate II.

211 Type the shunt value displayed on the “Shaft Torque” Daytronic in the “High Engineering Value” field. Hold down the Daytronic “+Cal” button and press <Return>.

212 The Cellmate II will prompt: “Comments?” Enter comments as necessary.

213 The Cellmate II will prompt:

“Do you wish to review or change any answers? (Y/N)” Press <Y> <Return> to review or change, or <N> <Return> to end the shaft torque calibration.

214 When the Cellmate II calibration has been completed, press <MENU>, this will display the “TESTING MENU” screen.

215 Press <2> <Return>. This will display the “TEST SEQUENCES” screen.

216 Press <2> <Return>. This will display the “TRANSIENT TESTS” screen.

217 Press <4> <Return>. This will display real-time measurements of test parameters.

218 Hold down <CTRL> and press <NEXT DISP> (upper left of keyboard). A new display will appear. Repeat <CTRL> <NEXT DISP> to move to the next screen which will display the shaft torque, case torque, and speed.

300 Shaft-Torque Linearity Verification

301 Place the hanger on the lever arm clevis and add Weights 2R and 4R. The weights must not swing on the lever arm during verification.

302 On Form 251-01, record the value displayed on the Daytronic, on the line labeled “Hanger, 2R, 4R,” and the column labeled “Daytronic Shaft Torque.”

303 On the same line under “Cellmate Shaft Torque,” record the shaft-torque value displayed on the Cellmate II.

304 Add weights 5R, 6R, and 7R on the hanger.

On Form 251-01, record the shaft-torque values displayed on the Daytronic and Cellmate II in the corresponding lines and columns.

305 Continue adding weights on the hanger, and recording the values on the corresponding lines on Form 251-01, until the complete set has been added.

306 After all the weights have been placed on the hanger, and the readings have been recorded, remove the top two weights (this should be weights 23S and 24S).

307 On Form 251-01, record the shaft torque values from the Daytronic and Cellmate II on the corresponding lines.

308 Continue removing weights and recording the values until no weight remains on the lever arm.

309 Verify that the shaft-torque values displayed on both the Daytronic and Cellmate II are 0.0 ±0.5.

If this tolerance is not met, repeat Steps 102 through 309.

310 Remove the lever arm and dyno lock from the dyno shaft.

311 Again, verify that the shaft-torque values displayed on both the Daytronic and Cellmate II are 0.0 ±0.5.

If this tolerance is not met, investigate possible lever arm imbalance and repeat Steps 102 through 309.

If this tolerance still cannot be met, notify the C&M supervisor.

400 Case-Torque Daytronic Calibration

401 On Form 251-01, record the shunt value that is displayed on the adhesive sticker adjacent to the "Case Torque" Daytronic, in the box labeled "Prev Case Torque Shunt Value."

402 Adjust the "Case Torque" Daytronic signal conditioner display to exactly 0.0 by rotating the "Fine Balance" potentiometer.

403 Hang all the calibration weights to be used on the case-torque lever arm. Refer to Form 251-01 for the weights to be used.

Remove hysteresis from the load cell by tapping its base with a rubber mallet after adding or removing any weight.

404 Adjust the "Case Torque" Daytronic, so the display matches the total moment created by the lever arm. To do this, adjust the span potentiometer so the display reads 1484.0. The Daytronic is adjustable to ±0.5.

Note: All weights hanging on the lever arm will equal 494.74 lb x 3.0 ft = 1484.2 ft-lb.

405 Using the hydraulic lift, raise the weights and the hanger off the lever arm clevis to recheck the zero calibration. Adjust the "Case Torque" Daytronic to exactly 0.0, if necessary, by rotating the "Fine Balance" potentiometer.

406 Repeat Steps 402-405 for zero and span until the "Case Torque" Daytronic readings are correct and repeatable.

407 Press the "+CAL" button on the "Case Torque" Daytronic. The value that is displayed will be the new shunt calibration value. On a new adhesive sticker, record this value, your initials, and the date. Remove the old sticker and post the new sticker next to the display.

408 On Form 251-01, record the new shunt calibration value in the box labeled "New Case Torque Shunt Value." This value should not differ by more than 5 percent from the "Prev Case Torque Shunt Value" unless repairs have been made or new equipment has been installed. If it does differ by more than 5 percent , notify the C&M supervisor.

409 Remove the weights from the hanger, and set the weights and hanger aside.

410 Verify that the Cellmate II display for "CTORQUE" agrees exactly with the Daytronic reading for zero. Press the "+CAL" button on the "Case Torque" Daytronic and ensure that the readings on the two displays agree exactly.

If they do not agree, proceed with Section 500.

If the readings agree, proceed with Section 600.

500 Cellmate II Case-Torque Calibration

This section should only be used if the "CTORQUE" readings on the Cellmate II display did not agree with the "Case Torque" Daytronic readings for the zero and span as observed in Section 400.

501 Press <MENU>. This will display the "TESTING MENU" screen.

502 Press <1> <Return>. This will display the calibration screen.

503 The first “CAL SCREEN” will display “CTORQUE."

504 Using <⇓>, scroll to “CTORQUE." It will become highlighted.

505 Press <Return> on the Cellmate II keyboard to enter the calibration mode.

Note: If you do not want to change an entry on the Cellmate II, press <Return> and it will retain the entry currently on the screen.

506 Type your initials and press <Return>.

507 Type the transducer serial number and press <Return>.

Note: This number only changes if the transducer is replaced.

508 With the weights raised off the clevis, and the “Case Torque” Daytronic display reading 0.0, press <Return> to enter the zero calibration into the Cellmate II.

509 Enter “0.0” and press <Return> to enter the zero value in the “Low Engineering Value” field.

510 Press and hold the “Case Torque” Daytronic “+CAL” button to display the new shunt value. With the “Case Torque” Daytronic reading the shunt value, press <Return> to enter the high value of the calibration into the Cellmate II.

508 Type the shunt value displayed on the “Case Torque” Daytronic in the “High Engineering Value” field. Hold down the Daytronic “+Cal” button and press <Return>.

509 The Cellmate II will prompt: “Comments?” Enter comments as necessary.

510 The Cellmate II will prompt:

“Do you wish to review or change any answers? (Y/N)” Press <Y> <Return> to review or change or <N> <Return> to end the case torque calibration.

511 When the Cellmate II calibration has been completed, press <MENU>, this will display the “TESTING MENU” screen.

512 Press <2> <Return>. This will display the “TEST SEQUENCES” screen.

513 Press <2> <Return>. This will display the "TRANSIENT TESTS" screen.

514 Enter <4> <Return>. This will display the real-time measurements of test parameters.

515 Hold down <CTRL> and press <NEXT DISP> (upper left of keyboard). A new display will appear. Repeat <CTRL> <NEXT DISP> to move to the next screen which will display the shaft torque, case torque, and speed.

600 Case-Torque Linearity Verification

601 Place the hanger on the lever arm clevis and add Weights 2R and 4R. Weights must not swing on the lever arm during verification.

602 On Form 251-01, record the value displayed on the Daytronic, on the line labeled "Hanger, 2R, 4R," and the column labeled "Daytronic Case Torque."

603 On the same line under "Cellmate Case Torque," record the case-torque value displayed on the Cellmate II.

604 Add weights 5R, 6R, and 7R on the hanger.

On Form 251-01, record the case torque values displayed on the Daytronic and Cellmate II in the corresponding lines and columns.

605 Continue adding weights on the hanger, and recording the values on their corresponding lines on Form 251-01, until the complete set has been added.

606 After all the weights have been placed on the hanger and the readings have been recorded, remove the top two weights (this will be weights 23S and 24S).

607 On Form 251-01, record the case-torque values from the Daytronic and Cellmate II on the corresponding lines.

608 Continue removing weights and recording the values until no weight remains on the lever arm.

609 Verify that the case-torque values displayed on both the Daytronic and Cellmate II are 0.0 ±0.5.

If this tolerance is not met, repeat Steps 402 through 609.

610 When the verification is complete, return the weights to their storage location.

700 Speed Verification

The speed measurement system is typically very stable and does not require adjustment. If the equipment fails any part of this verification, it should be taken out of service and a possible equipment malfunction should be investigated.

701 Verify that the Cellmate II display for "SPEED" agrees exactly with the Daytronic reading for the zero.

702 Press and hold the "SPAN" button on the "SPEED" Daytronic. Verify that the Cellmate II display for "SPEED" agrees exactly with the Daytronic reading for span.

703 Unplug the rotary transformer speed sensor cable (the smaller of two cables) from the dynamometer shaft-torque transducer.

704 Connect the Fluke multi-counter to the transducer using the cable labeled "Dyno Cal," which is stored in the large tool box in the test cell.

705 Press the "Freq" and "Auto" buttons on the counter. The counter will automatically set itself to the correct scale to measure the dynamometer revolutions per minute.

706 Turn the "AUTO/MANUAL" switch on the Cellmate II to the "MANUAL" position.

707 Turn the dyno "POWER" switch to the "ON" position.

708 Turn the "FUEL/IGNITION" switch to the "ON" position.

709 Press the "RESET" button. This will cause the green "FUEL ON" light to illuminate.

710 Press the "DYNO ON" button. This will cause it to illuminate.

711 Turn the variable voltage power supply unit to "OFF."

712 Press the "MANUAL" button on the dyno control panel.

713 Control the dyno rpm with the "SPEED" potentiometer on the right side of the control panel. Speed will be set by observing the multi-counter display and adjusting the speed to exactly those speeds shown on Form 251-01.

714 Verify the accuracy of the "SPEED" Daytronic display and the Cellmate II display by operating the dynamometer at 200 rpm and then from 500 to 4500 rpm at 500 rpm increments. Compare the readings at each point to the readings on the multi-counter display.

On Form 251-01, record the readings under the columns labeled "Daytronic Speed" and "Cellmate Speed."

Both the Daytronic and Cellmate II readings must be within ±2 percent of the multi-counter readings.

715 Turn the "POWER" switch on the dyno control panel to "OFF."

716 Turn the "FUEL/IGNITION" switch to "OFF."

717 Press the "MG SET" "STOP" button.

718 When verification is complete, reinstall the sensor cable into the transducer and return the multi-counter and connection cable to their storage areas.

719 End the calibration procedure on the Cellmate II:

Press <MENU>. The "TESTING MENU" will appear on the screen.

Press <6> <Return>.

Leave the Cellmate II power "ON."

9. Data Input

9.1 The technician will enter all calibration and verification data required on Form 251-01.

9.2 For each Daytronic torque signal conditioner, the technician will put his/her initials, the date, and the new shunt calibration value on an adhesive sticker and post the sticker next to the signal conditioner.

9.3 The technician will enter all data from Form 251-01 into the Excel® spreadsheet upon completion of the calibration.

9.3.1 Locate a Macintosh computer that has access to the Labrotory Network System (LNS).

9.3.2 Sign on to the LNS Production Server.

9.3.3 Open the “C&M” folder, then open the “TP 251 (Dyno Cal)” folder.

9.3.4 Open the “Speed and Torque Cal Report” spreadsheet.

9.3.5 Transcribe the data from Form 251-01 to the spreadsheet. When it is complete, print the spreadsheet for review. Printing the spreadsheet creates the “Heavy-Duty Speed and Torque Calibration Report.”

9.3.6 Save the completed file as “Speed and Torque Cal Report mm/dd/yy” with the date included in the title.

9.3.7 Close the file and the “TP 251 (Dyno Cal)” folder and sign off of LNS.

10. Data Analysis

10.1 The technician will check Form 251-01 and the “Heavy-Duty Speed and Torque Calibration Report” for transcription accuracy.

10.2 The computer automatically compares the observed torque value to the theoretical or calculated value and calculates the percent deviation for each point. The technician will review the computer printout to ensure that all acceptance criteria have been met.

If all acceptance criteria have been met, the technician signs and dates Form 251-01.

10.3 A technician other than the technician who entered the data, reviews Form 251-01 and the “Heavy-Duty Speed and Torque Calibration Report” for transcription accuracy to ensure that all acceptance criteria are met. If this verification is successful, the technician signs and dates the “Heavy-Duty Speed and Torque Calibration Report.”

If all acceptance criteria have been met, the equipment may be placed back in service.

If the acceptance criteria have not been met, the equipment must be taken out of service until it can be adjusted, repaired, or replaced and the verifications outlined in this procedure are completed successfully.

11. Data Output

The completed Form 251-01 and the “Heavy-Duty Speed and Torque Calibration Report” are filed in the C&M Department Calibration File.

12. Acceptance Criteria

12.1 The torque values indicated on the Cellmate II and the Daytronic signal conditioners must be within ±3 percent or 10 ft-lb of the calculated value, whichever is less, for each point.

12.2 The speed values indicated on the Cellmate II and the “Speed” Daytronic both must be within 2 percent of the Fluke multi-counter readings.

12.3 Final zero-point torque readings must be within ±0.5 ft-lb on both the Cellmate II and Daytronic readouts.

13. Quality Provisions

13.1 Weights must not swing on the lever arm during a calibration.

13.2 Speed and Torque calibrations on the dynamometer must be performed monthly or whenever any portion of the torque or speed measurement system is repaired or replaced.

13.3 Speed and torque signals are checked for accuracy and linearity throughout their entire working range.

13.4 The calibration weights must be traceable to NIST standards.

Attachment A

Heavy-Duty Dynamometer Speed and Torque Calibration

Weight ID Numbers	NIST Weight (lb)	Daytronic Shaft Torque (ft-lb)	Cellmate Shaft Torque (ft-lb)	Daytronic Case Torque (ft-lb)	Cellmate Case Torque (ft-lb)
	0.00				
Hanger, 2R, 4R	24.675				
5R, 6R, 7R	54.538				
8R, 8S	89.792				
9S, 10S	140.548				
11S, 12S	191.627				
13S, 14S	242.020				
15S, 16S	292.802				
17S, 18S	343.282				
19S, 20S	393.757				
21S, 22S	444.378				
23S, 24S	494.739				
23S, 24S	494.739				
21S, 22S	444.378				
19S, 20S	393.757				
17S, 18S	343.282				
15S, 16S	292.802				
13S, 14S	242.020				
11S, 12S	191.627				
9S, 10S	140.548				
8R, 8S	89.792				
5R, 6R, 7R	54.538				
Hanger, 2R, 4R	24.675				
	0.00				

Multi-Counter Speed (rpm)	Daytronic Speed (rpm)	Cellmate Speed (rpm)
200		
500		
1000		
1500		
2000		
2500		
3000		
3500		
4000		
4500		

Shaft Torque Shunt Value	
Previous	
New	

Case Torque Shunt Value	
Previous	
New	

Comments

I have performed this calibration in accordance with TP 251.

Technician Signature _____ Date _____

Form 251-01: 12-19-94

HEAVY-DUTY SPEED AND TORQUE CALIBRATION REPORT 12/13/94

Weight ID	NIST Weight (lb)	Total NIST Weight (lb)	Calc. Case Torque (ft-lb)	Calc. Shaft Torque (ft-lb)	Daytronic Shaft Torque (ft-lb)	Cellmate Shaft Torque (ft-lb)	Daytronic Case Torque (ft-lb)	Cellmate Case Torque (ft-lb)	Daytronic Shaft Torque Offset (ft-lb)	% diff.
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Hanger, 2R, 4R	24.675	24.675	74.0	61.7	61.0	61.4	74.0	74.2	-0.7	-1.11%
5R, 6R, 7R	29.863	54.538	163.6	136.3	137.0	136.9	164.0	164.1	0.7	0.48%
8R, 8S	35.255	89.792	269.4	224.5	224.0	224.3	269.5	269.5	-0.5	-0.21%
9S, 10S	50.755	140.548	421.6	351.4	352.0	351.5	421.5	421.4	0.6	0.18%
11S, 12S	51.079	191.627	574.9	479.1	479.0	479.3	575.0	575.2	-0.1	-0.01%
13S, 14S	50.393	242.020	726.1	605.0	607.0	607.1	728.0	728.1	2.0	0.32%
15S, 16S	50.782	292.802	878.4	732.0	735.0	735.5	881.5	881.3	3.0	0.41%
17S, 18S	50.481	343.282	1029.8	858.2	860.0	860.1	1030.5	1031.0	1.8	0.21%
19S, 20S	50.474	393.757	1181.3	984.4	984.0	984.3	1182.5	1182.4	-0.4	-0.04%
21S, 22S	50.622	444.378	1333.1	1110.9	1109.5	1109.7	1332.0	1332.2	-1.4	-0.13%
23S, 24S	50.360	494.739	1484.2	1236.8	1235.0	1235.1	1481.5	1481.7	-1.8	-0.15%
23S, 24S	50.360	494.739	1484.2	1236.8	1235.0	1235.2	1481.5	1481.7	-1.8	-0.15%
21S, 22S	50.622	444.378	1333.1	1110.9	1109.0	1109.8	1332.5	1332.4	-1.9	-0.18%
19S, 20S	50.474	393.757	1181.3	984.4	983.0	983.3	1182.0	1182.2	-1.4	-0.14%
17S, 18S	50.481	343.282	1029.8	858.2	859.0	859.1	1031.0	1031.2	0.8	0.09%
15S, 16S	50.782	292.802	878.4	732.0	734.5	734.6	881.5	882.0	2.5	0.34%
13S, 14S	50.393	242.020	726.1	605.0	607.0	607.1	727.0	727.2	2.0	0.32%
11S, 12S	51.079	191.627	574.9	479.1	480.0	479.9	575.0	575.6	0.9	0.19%
9S, 10S	50.755	140.548	421.6	351.4	352.5	352.4	422.0	422.2	1.1	0.32%
8R, 8S	35.255	89.792	269.4	224.5	226.0	224.7	269.5	270.0	1.5	0.68%
5R, 6R, 7R	29.863	54.538	163.6	136.3	137.5	137.4	164.5	164.9	1.2	0.85%
Hanger, 2R, 4R	24.675	24.675	74.0	61.7	61.5	61.4	73.5	74.0	-0.2	-0.30%
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

NIST CERTIFIED WEIGHTS

Weight ID	Weight (lb)	Weight ID	Weight (lb)
Hanger =	09.68644	13S =	25.52237
2R =	05.00871	14S =	24.87054
4R =	09.97989	15S =	25.56443
5R =	10.01902	16S =	25.21751
6R =	09.84235	17S =	25.28046
7R =	10.00126	18S =	25.20028
8R =	10.02786	19S =	25.25228
8S =	25.22672	20S =	25.22205
9S =	25.25314	21S =	25.47852
10S =	25.50234	22S =	25.14300
11S =	25.48440	23S =	25.17076
12S =	25.59476	24S =	25.18945

Example Data Only

Version 1.0:5/26/94

Attachment B Continued

HEAVY-DUTY SPEED AND TORQUE CALIBRATION REPORT 12/13/94

Cellmate Shaft Torque Offset (ft-lb)	% diff.	Daytronic Case Torque Offset (ft-lb)	% diff.	Cellmate Case Torque Offset (ft-lb)	% diff.
0.0		0.0		0.0	
-0.3	-0.47%	0.0	-0.03%	0.2	0.24%
0.6	0.41%	0.4	0.24%	0.5	0.30%
-0.2	-0.08%	0.1	0.05%	0.1	0.05%
0.1	0.04%	-0.1	-0.03%	-0.2	-0.06%
0.2	0.05%	0.1	0.02%	0.3	0.06%
2.1	0.34%	1.9	0.27%	2.0	0.28%
3.5	0.48%	3.1	0.35%	2.9	0.33%
1.9	0.22%	0.7	0.06%	1.2	0.11%
-0.1	-0.01%	1.2	0.10%	1.1	0.10%
-1.2	-0.11%	-1.1	-0.09%	-0.9	-0.07%
-1.7	-0.14%	-2.7	-0.18%	-2.5	-0.17%
-1.6	-0.13%	-2.7	-0.18%	-2.5	-0.17%
-1.1	-0.10%	-0.6	-0.05%	-0.7	-0.06%
-1.1	-0.11%	0.7	0.06%	0.9	0.08%
0.9	0.10%	1.2	0.11%	1.4	0.13%
2.6	0.35%	3.1	0.35%	3.6	0.41%
2.1	0.34%	0.9	0.13%	1.1	0.16%
0.8	0.17%	0.1	0.02%	0.7	0.13%
1.0	0.29%	0.4	0.08%	0.6	0.13%
0.2	0.10%	0.1	0.05%	0.6	0.23%
1.1	0.77%	0.9	0.54%	1.3	0.79%
-0.3	-0.47%	-0.5	-0.71%	0.0	-0.03%
0.0		0.0		0.00	

Speed Calibration

Multi-Counter Speed	Daytronic Speed	% Diff	Cellmate Speed	% Diff
200	199	-0.5%	199	-0.5%
500	499	-0.2%	500	0.0%
1000	1000	0.0%	1000	0.0%
1500	1500	0.0%	1500	0.0%
2000	2001	0.1%	2001	0.1%
2500	2501	0.0%	2500	0.0%
3000	3002	0.1%	3001	0.0%
3500	3502	0.1%	3501	0.0%
4000	4002	0.1%	4001	0.0%
4500	4501	0.0%	4500	0.0%

Torque Shunt Values

	Shaft Torque	Case Torque
Prev.	1065.5	1195.0
New	1066.0	1196.0
% Difference	0.05%	0.08%

I have performed this calibration in accordance with T.P. 251.

Example Data Only

Technician Signature _____ Date _____

I have validated this data in accordance with TP 251.

Technician Signature _____ Date _____